APPENDIX 8-8

SEEPAGE CONTROL TECHNICAL MEMORANDUM II

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BLACK & VEATCH

TECHNICAL MEMORANDUM

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Task 7.1.1.3.2 Seepage Control Technical Memorandum II

To: Distribution

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1. INTRODUCTION

In October 2003, South Florida Water Management District (District) decided to pursue a "Dual Track" for the Everglades Agricultural Area (EAA) Reservoir project. While the multi-agency Project Delivery Team, lead by the Corps of Engineers, continues to develop the Project Implementation Report, the District is proceeding with the design of a reservoir (designated EAA Reservoir A-1 Project) located on land acquired through the Talisman exchange in the Everglades Agricultural Area.

The purpose of the Project as defined in the CERP is to capture EAA Basin runoff and releases from Lake Okeechobee. The facilities will be designed to improve the timing of environmental water supply deliveries to STA 3/4 (Storm Water Treatment Area 3/4) and the WCAs (Wetland Conservation Areas), reduce Lake Okeechobee regulatory releases to the estuaries, meet agricultural irrigation demands, and increase flood protection within the EAA.

This Seepage Control Technical Memorandum II follows the Seepage Control Technical Memorandum under Work Order 2 (WO2) which was prepared prior to this memorandum. The Seepage Control Technical Memorandum under WO2 summarizes the results of deep seepage modeling based on data obtained from test cells construction under that same work order.

2. OBJECTIVES

[Since the issuance of this memorandum, additional modeling has been performed with the modeling program MODFLOW. The details of this modeling is presented in the Groundwater Model Memorandum and added as Appendix 6-2 of the BODR. Due to the more accurate 3-D modeling capabilities of MODFLOW, additional cost analysis was performed on seepage rates from MODFLOW. Tables summarizing this information are given as "updated" tables and immediately follow the corresponding table using SEEP/W results. Since a trend of cost effectiveness for a shallower seepage canal was observed from the SEEP/W results, only the 10' deep canal results from MODFLOW were included herein. Additionally, MODFLOW is able to quantify what portion of total seepage is observed in various sections of Reservoir A-1. Therefore, since A-2 will be online in 2015, seepage recovery costs along this portion of the reservoir was only included for the six years between the Reservoir A-1 scheduled completion

date of 2009 and the Reservoir A-2 date of 2015. Finally, it should be noted that Updated Table 6 shows the shallow cutoff wall as more cost effective compared to the deep cutoff wall. This contradicts what was shown in Table 6 of the draft memorandum, and is largely due to the more accurate groundwater seepage modeling of MODFLOW which resulted in lower seepage rates than were originally computed with SEEP/W.]

The objectives of this Technical Memorandum are to:

- Summarize five seepage control components – a shallow seepage canal, a deep seepage canal, a key trench cutoff, a shallow cutoff wall, and a deep cutoff wall
- Discuss cost implications of various construction methods for construction of the seepage control components
- Discuss costs associated with recovery of seepage at various seepage rates associated with the differing seepage control components
- Summarize the cost of each seepage control component and appropriate seepage recovery effort for Reservoir A-1

3. SEEPAGE CONTROL COMPONENTS CONSTRUCTION

3.1 General

Under Work Order 2, deep seepage alternatives were modeled. These alternatives varied by depth of cutoff, depth of seepage collection canals, and the location of the seepage cutoff canal. The full results of this modeling can be found in the Seepage Control Technical Memorandum under WO2. A general schematic of seepage control components as modeled in that memorandum is shown in Figure 2. This memorandum summarizes the cost associated of typical components of that modeling. Therefore, comparative costs were derived for a shallow seepage collection canal, a deep seepage collection canal, a key trench cutoff (or core trench cutoff), a shallow soil-bentonite cutoff wall, and a deep soil-bentonite cutoff wall. These costs are summarized in Table 4, and are described in further detail below.

It is important to note that these seepage control structures will only be located adjacent to the east, north, and the north portion of the west reservoir embankment. Alternative embankments paralleling the STA 3/4 distribution canal will likely eliminate the need for seepage collection in this area. Once a design is selected along those borders, seepage concerns will need to be considered in light of the selection. Therefore, seepage collection costs per lineal foot of embankment are based only on those portions expected to have seepage control structures. This is illustrated in Figure 1.
Shallow Seepage Canal

For the shallow seepage canal case, a 10-ft deep canal with a 40-ft bottom width was selected. Furthermore, side slopes of 2H:1V were assumed. Material excavated from the canal was assumed to be fully used in an earthen embankment construction. Caprock and material from the Fort Thompson layer will be used in embankment construction while peat will be stripped and used to construct dewatering berms. Therefore, excavation of all material is included in the cost given herein while placement or stockpiling of the caprock and silty sand are not included. Drilling and blasting was assumed necessary for removal of any caprock within the canal. Furthermore, the underlying Fort Thompson material was assumed to be removed with an excavator and then stockpiled between the canal and the embankment location for later placement in the embankment. If an RCC embankment alternative is selected, additional cost for disposal of any material removed from the Fort Thompson layer would need to be considered.

Deep Seepage Canal

The assumptions described for the shallow seepage canal apply for the deep seepage canal as well, except for canal depth. The depth of the deep seepage canal was established at 20-ft deep. This depth requires excavation further into the Fort Thompson material such that the first layer of limestone identified during borings and construction of the test cells will be encountered. Compressive strengths of this material are such that the material can be excavated with a large excavator and will not require additional drilling and blasting. This level of effort was assumed for costs associated with the deep seepage canal.

Key Trench Cutoff

The excavation for a key trench cutoff was assumed to be similar to that for the seepage canal alternatives. The depth of the cutoff was assumed to be 10-ft while the bottom width was assumed at 15-ft. An impermeable fill in this trench would effectively cut off any seepage through and around the caprock. Furthermore, the side slopes were assumed to be 1H:1V and were assumed to be lined with 4 inches of shotcrete. A graphical representation of the keyway trench cutoff is shown in Figure 3.

Shallow Soil-Bentonite Cutoff Wall

Costs for a soil-bentonite cutoff wall were based on costs incurred during the construction of test cell 2, which included a cutoff through the caprock and a portion of the Fort Thompson layer, and on feedback from the contractor responsible for the construction of the test cell 2 cutoff wall. For the shallow cutoff wall component, a 2-ft wide by 26-ft deep cutoff wall was analyzed for cost. The cost of excavation through caprock was based on a contractor quote for use of a 2-ft wide rock trencher. This effort proved successful during test cell construction and is therefore a valid assumption. Cost for a caprock seal constructed of low strength concrete was also included in order to effectively cut off seepage through the caprock layer. Additional material below the caprock layer was assumed to be removed with an excavator for cost analysis purposes. As material is removed, soil-bentonite slurry is prepared with excavated material and placed back into the trench.

Deep Soil-Bentonite Cutoff Wall

For the deep cutoff wall component, a 2-ft wide by 70-ft deep cutoff wall was analyzed for cost. Though construction of the deep cutoff wall is similar to that of the shallow cutoff wall, there are several factors other than additional material to be removed, mixed with bentonite, and replaced that increase cost. First, an additional pass of the rock trencher is necessary, which results in a wider trench through the caprock layer. The wider trench is needed to allow for the knuckle of an excavator as it reaches down to the deep portions of the trench. Additionally, production rates decrease with the deeper trench, leading to a further increase in cost.

4. SEEPAGE RECOVERY COST

1.1 General

As shown in the Seepage Control Technical Memorandum under WO2, the different seepage control mechanisms will result in different seepage rates. This seepage will in turn be captured and returned to the reservoir to the maximum extent possible; this is the intent of the seepage canal. Therefore, it is equally important to quantify and compare present worth costs associated with this recovery as it is to quantify and compare the cost of capturing it via a canal or retarding it via a cutoff. For this purpose, present worth analysis was performed using the discount rate for water resources project as published in the federal register. This rate for 2005 is 5.375 percent.

1.2 Seepage Rates

Seepage rates were modeled with the modeling software SEEP/W by Geo-slope International as discussed in the Seepage Control Technical Memorandum under WO2. These rates provide the basis of seepage recovery costs. According to the Seepage Control TM under WO2, permeability rates were calibrated using SEEP/W as well as MODFLOW. As there are two types of seepage control components, cutoffs and canals, there are multiple combinations of components that can recover different amounts of seepage. For example, for a 26-ft cutoff, a deep seepage canal should recover a greater amount than a shallow seepage canal, while the remaining seepage is lost to the background.

Furthermore, seepage rates were modeled at a water depth of 12-ft. However, over the 50-year design period selected for analysis, a water depth of 6’ is more appropriate as a normal operating depth. During operation of the test cells, it was noted that seepage rates tended to decrease linearly with decreases in water depth. This trend was applied to modeled seepage rates in order to obtain a seepage rate for 6’ of depth. Therefore, the more conservative seepage rates obtained from either SEEP/W or MODFLOW permeability rates for each seepage control combination and modified for a normal operating depth of 6-ft are reported in a matrix given in Table 1.

1.3 Pumps

Once recoverable seepage rates were established, potential seepage pumps were selected. Pumps were selected based on the high flow, low head condition that exists for a new pump station or a modification to one or both of the existing pump stations (G-370 and G-372). Pumps were selected from a Black & Veatch pump database that documents costs for various pumps based on flow and head requirements. The pump selected was a 100-cfs flow, 30-ft head pump. This is comparable to the 75 cfs pumps that are currently in use at Pump Station G-370. As the deep cutoff wall resulted in a lower seepage rates, smaller pumps were selected for that alterative. The pump selected for this case was a 60-cfs, 30-ft head pump. Once pumps were determined, the number of pumps was established based on the seepage recovery rates above. In addition to the initial pump cost, replacement pump costs were determined for years 15, 30, and 45 over the 50 year time period for analysis. All of these costs were finally adjusted to present worth. The present worth of initial pump and replacement pump costs are given in Table 2.

1.4 Power Generation

In addition to pump costs, power costs were determined for operation of those pumps over the 50 year period. The existing pump stations have diesel generators for on-site power generation. Therefore, the costs of new generators and diesel fuel was also included over the 50 year period. As with the pump costs, replacement generator costs were determined for years 20 and 40 over the 50 year time period for analysis. Fuel costs, established over the 50-yr period based on a price of $2.25 per gallon with an inflation rate of 2.97%, proved to be the single greatest contributor to seepage recovery costs, in most cases, accounting for just over 50% of the total seepage collection and recovery cost. See Table 3.

5. RESULTS

5.1 Cost Comparison Summary

See Tables 4-5

5.2 Discussion of Costs

Important to note in the seepage recovery costs are that the comparative costs only include the costs of seepage control such as cutoff wall and seepage recovery such as seepage pumps, generators, and operation costs of those pieces of equipment over a 50-year design period. The cost of additional space requirements to house the seepage pumps and associated equipment in a new pump station and the cost of retrofitting the seepage pumps in one or both of the existing pump stations has not been included at this time. Based on this analysis, it appears that the most cost effective seepage collection configuration is the shallow cutoff of 26-ft deep with a shallow seepage canal. However, if the trends observed in Table 6 hold, the 70-ft deep cutoff with a shallow seepage canal should be modeled.

6. REFERENCES

Seepage Control Technical Memorandum (Work Order No. 2)

Test Cell Construction and Seepage Monitoring Report

TABLES

Table 1 - Modeled Seepage Rates (cfs)		
	Shallow Seepage	Deep Seepage
	Canal (10' deep)	Canal (20' deep)
Key Trench Cutoff (10' deep)	*not modeled*	198
Shallow Soil-Bentonite Cutoff (26' deep)	141	166
Deep Soil-Bentonite Cutoff (70' deep)	*not modeled*	32

Updated Table 1 - Modeled Seepage Rates (cfs)		
	Section A & B	Along A-2
	10' Deep Canal	10' Deep Canal
Shallow Soil-Bentonite Cutoff (34' deep)	124	20
Deep Soil-Bentonite Cutoff (69' deep)	72	12

Table 2 - Pump Present Worth ($)		
	Shallow Seepage	Deep Seepage
	Canal (10' deep)	Canal (20' deep)
Key Trench Cutoff (10' deep)	*not modeled*	$6,705,885
Shallow Soil-Bentonite Cutoff (26' deep)	$6,705,885	$6,705,885
Deep Soil-Bentonite Cutoff (70' deep)	*not modeled*	$1,297,913

Updated Table 2 - Pump Present Worth ($)	
	Section A & B
	10' Deep Canal
Shallow Soil-Bentonite Cutoff (34' deep)	$2,595,826
Deep Soil-Bentonite Cutoff (69' deep)	$1,946,870

Table 3a - Generator Present Worth ($)		
	Shallow Seepage	Deep Seepage
	Canal (10' deep)	Canal (20' deep)
Key Trench Cutoff (10' deep)	*not modeled*	$10,952,839
Shallow Soil-Bentonite Cutoff (26' deep)	$7,731,415	$9,148,842
Deep Soil-Bentonite Cutoff (70' deep)	*not modeled*	$1,803,997

Updated Table 3a - Generator Present Worth ($)	
	Section A & B
	10' Deep Canal
Shallow Soil-Bentonite Cutoff (34' deep)	$6,829,417
Deep Soil-Bentonite Cutoff (69' deep)	$3,994,565

Table 3b - Fuel Costs Present Worth ($)		
	Shallow Seepage	Deep Seepage
	Canal (10' deep)	Canal (20' deep)
Key Trench Cutoff (10' deep)	*not modeled*	$21,253,880
Shallow Soil-Bentonite Cutoff (26' deep)	$15,002,739	$17,753,244
Deep Soil-Bentonite Cutoff (70' deep)	*not modeled*	$3,500,636

Updated Table 3b - Fuel Costs Present Worth ($)	
	Section A & B
	10' Deep Canal
Shallow Soil-Bentonite Cutoff (34' deep)	$13,902,678
Deep Soil-Bentonite Cutoff (69' deep)	$8,157,839

Table 4 - Seepage Control Components Construction Costs	
	Construction
	Cost per Lin. Ft.
Shallow Seepage Canal (10' deep)	$412
Deep Seepage Canal (20' deep)	$723
Key Trench Cutoff (10' deep)	$264
Shallow Soil-Bentonite Cutoff (26' Deep)	$409
Deep Soil-Bentonite Cutoff (70' Deep)	$729

Table 5 - Comparative Seepage Recovery Costs ($/ft)		
	Shallow Seepage	Deep Seepage
	Canal (10' deep)	Canal (20' deep)
Key Trench Cutoff (10' deep)	*not modeled*	$908.43
Shallow Soil-Bentonite Cutoff (26' deep)	$687.29	$784.59
Deep Soil-Bentonite Cutoff (70' deep)	*not modeled*	$154.14
** All costs are relevant per linear foot of embankment		

Updated Table 5 - Comparative Costs ($/ft)	
	Section A & B
	10' Deep Canal
Shallow Soil-Bentonite Cutoff (34' deep)	$467
Deep Soil-Bentonite Cutoff (69' deep)	$283

Table 6 - Total Comparative Seepage Control Costs (Construction & PW Recovery)		
	Shallow Seepage	Deep Seepage
	Canal (10' deep)	Canal (20' deep)
Key Trench Cutoff (10' deep)	*not modeled*	$1,833.39
Shallow Soil-Bentonite Cutoff (26' deep)	$1,457.06	$1,862.15
Deep Soil-Bentonite Cutoff (70' deep)	*not modeled*	$1,593.15
** All costs are relevant per linear foot of embankment		

Updated Table 6 - Total Comparative Seepage Control Costs (Construction & PW Recovery)	
	Section A & B
	10' Deep Canal
Shallow Soil-Bentonite Cutoff (34' deep)	$1,289
Deep Soil-Bentonite Cutoff (69' deep)	$1,425
** All costs are relevant per linear foot of embankment	

FIGURES

Figure 1 Seepage Control Layout

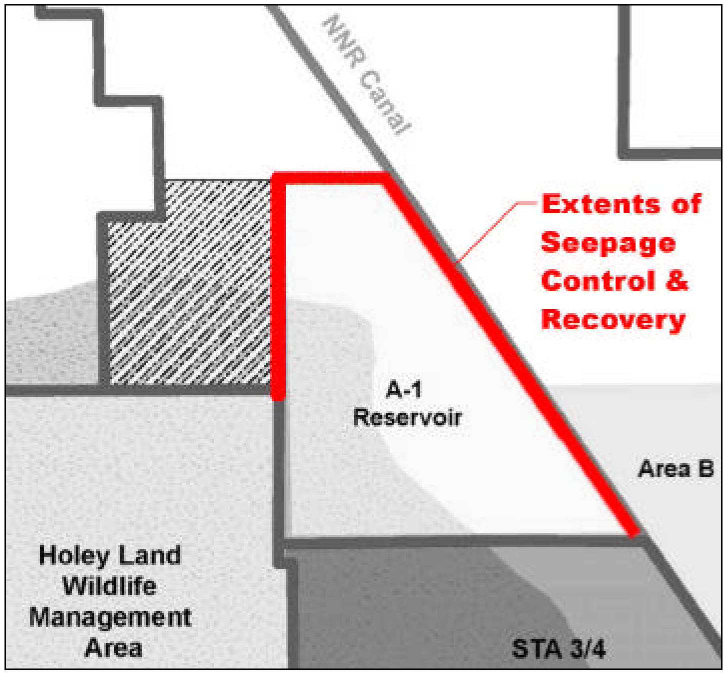

Figure 2 Typical Seepage Control Components

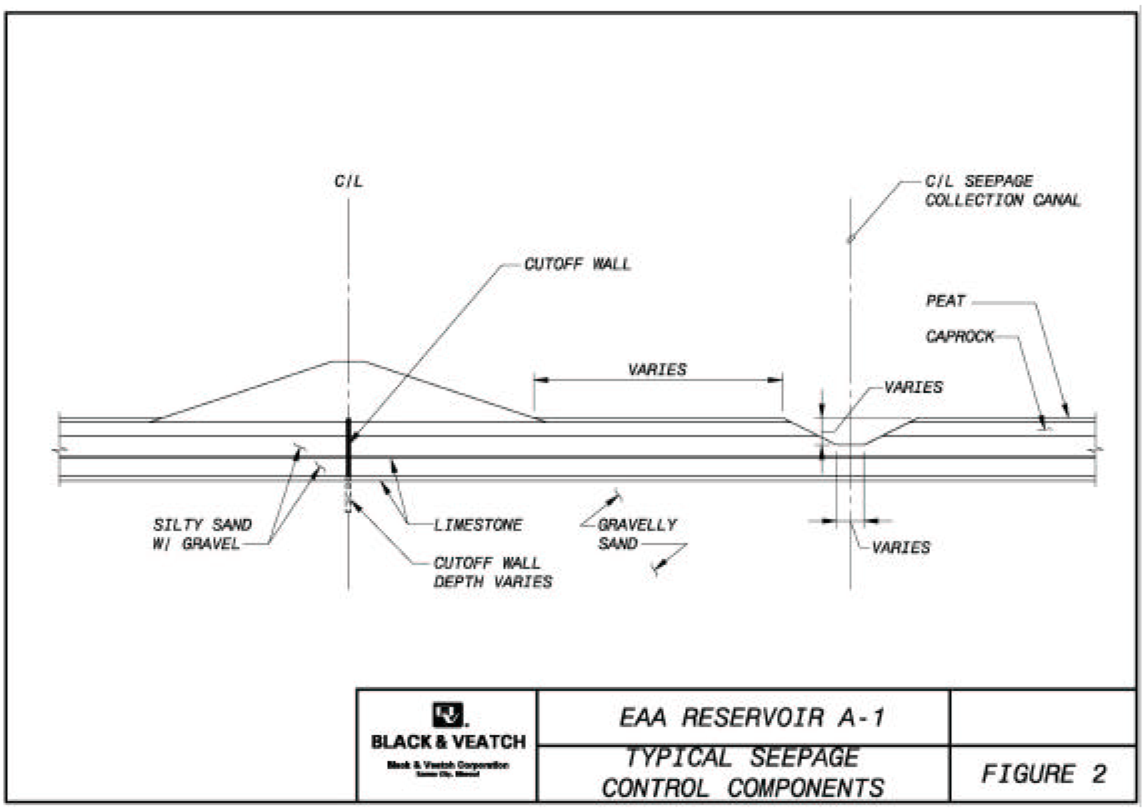

Figure 3 Keyway Trench Cutoff